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THE NATURE AND CAUSES OF INVIABILITY AND DELAYED GERMINATION IN SEED OATS

Norman Gable Lewis
Department of Field Crops

University of Alberta

April, 1938

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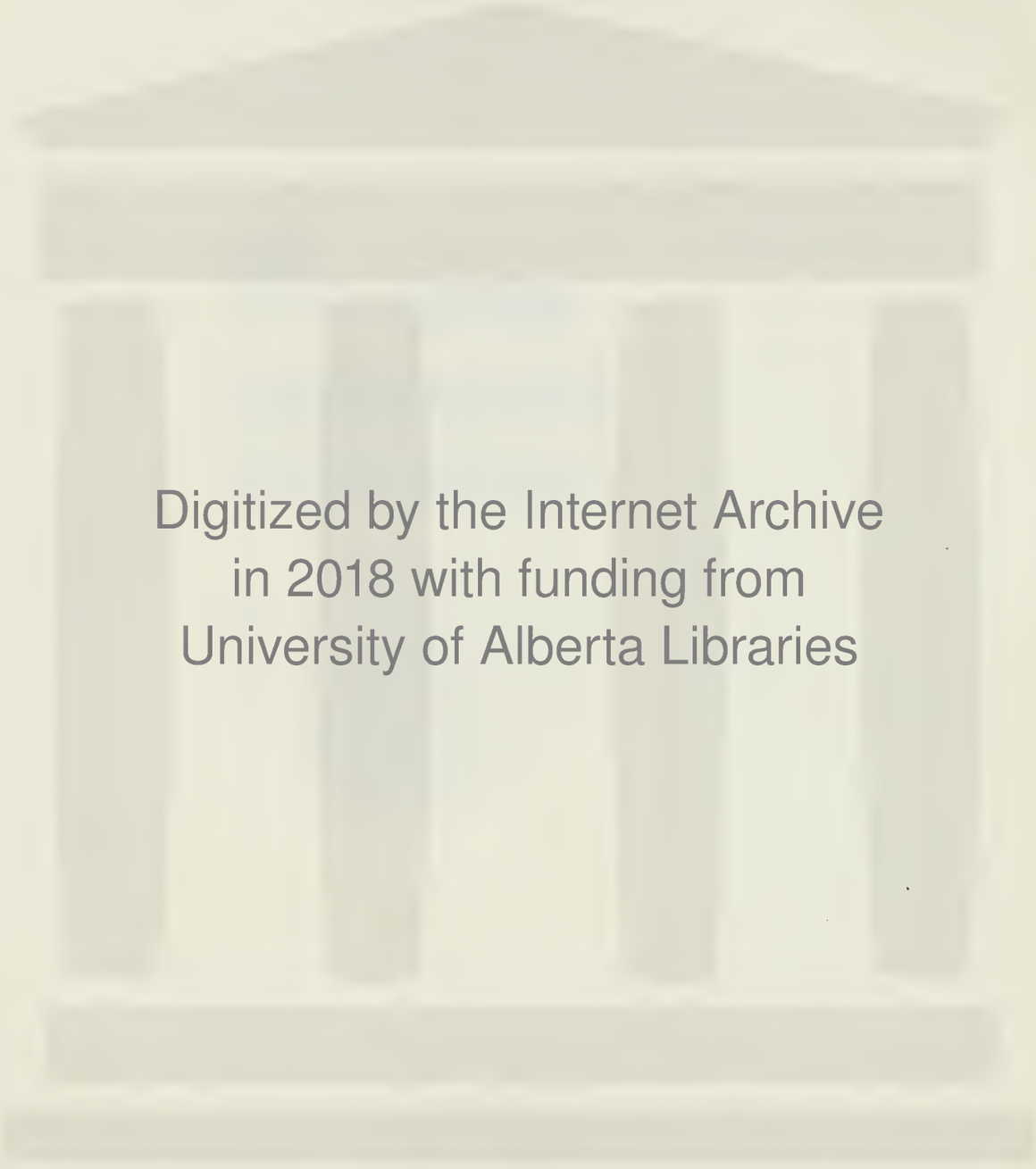

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Norman Gable Lewis
Department of Field Crops

A THESIS
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TABLE OF CONTENTS

	Page
Summary	1
Introduction	2
Factors in the Production of the Crop of 1935	3
History of Samples Received at Laboratory	4
Method of Testing	4
Interpretation of Tests	4
Behaviour of Samples in Test	5
Review of Literature	6
Material and Methods	12
Methods in the Controlled Temperature Experiment of 1936	13
Methods in Field Experiment of 1936	14
Results of Controlled Temperature Experiment 1936.	15
Results of Field Experiment of 1936	24
Production of Oats Showing Delayed Germination in 1937	37
Discussion	43
Acknowledgment	45
Appendix	

NOTE:

Owing to the fact that results from 1937 material will not be available until July 1938, presentation of results in complete form is not possible at this time. When data are available, a supplement to this paper will be forwarded to the University.

Until this is available it seems unwise to draw conclusions. Such as seem permissible at this time are embodied in the discussion and in the abstract.

THE NATURE AND CAUSES OF INVIABILITY AND DELAYED GERMINATION IN SEED OATS

Norman Gable Lewis

ABSTRACT

The object of the investigation was the determination of circumstances under which the phenomenon of delayed germination in Avena sativa occurred, and the production at will, of material exhibiting the phenomenon. The latter was accomplished in the two years, under circumstances in which oats matured in September and were stored at low temperatures during the winter. The dormancy is not considered of greater depth than that in comparable material harvested earlier in the season, but it is

thought that it is preserved longer by low temperature. The dormant seed is fully germinable at a temperature of 15°C. but is inhibited in tests at 20°C. Probable causes of this inhibition are indicated in the results but, examination of the physiology of the problem is left for the final paper.

The effect of frost is not yet ascertained. It is shown, however, that seed producing normal seedlings from frosted samples behaves similarly in repeated tests to seed from non-frosted samples, and that a given sample may thus show both frost damage and delayed germination.

INTRODUCTION

The seed oat crop produced in 1935 in north central Alberta, exhibited a combination of immaturity, frost damage and delayed germination, causing difficulty in the Seed Laboratory throughout the winter testing season. With the object of producing oats of similar behaviour so that laboratory studies of the problem could proceed, this investigation was commenced in 1936. The report given here is preliminary in nature; complete data of the two years work not being yet available.

Factors in the Production of the crop of 1935

The crop was harvested in September, its growth period having been prolonged by rain and its maturing period by low autumn temperatures. Frost, varying in intensity with locality, occurred on August 16th when the crop was in the late flowering or early milk stage. Frost also occurred on September 4th, and a series of heavy frosts toward the latter part of September affected the very late grain. Winter temperatures commenced with the fall of permanent winter snow on October 7th. The following data are descriptive of the crop.

Rod Rows	Seeded	Cut	Height	Days from seeding to maturity.
Beaverlodge	May 22	Sept.8	45"	113
Edmonton	May 28	Sept.17	54"	112

From observations made in that year, the writer believes the data descriptive of the earlier cut oats in each district. Weather data show that sunshine hours were low in June and July and that temperatures during the maturing period were too low for very active vegetative activity or rapid drying of grain. Rainfall in the Peace River area established a record and the number of days per month on which rain fell was unusually high.

History of samples received at Laboratory

Samples were harvested during the low temperatures of autumn and stored during the winter at lower temperatures. Samples received at the laboratory would be drawn from bins at probably sub-zero temperature and would then travel in heated mail cars for from one to three days on their journey to the laboratory at Calgary. They might be tested immediately or filed for some time owing to pressure of work.

Method of Testing

The blotter test had been discarded for use in the case of immature or frosted seed, in favor of a test in sand at 18°C. to 20°C. Cardboard boxes, of sufficient volume for tests of 100 seeds were used, the seed being covered to a depth of one-half inch. Duplicate samples of 100 seeds each were germinated in a constant temperature room and counted at six and twelve day intervals.

Interpretation of Tests

Owing to shortage of good seed and to the expectation that much seed of low viability would be used by farmers in

the following spring, it was thought that official tests should not over-estimate the viability of samples. For this reason, seedlings without roots or shoots, or those showing marked abnormality, were counted as inviable.

Behaviour of Samples in Test

The germination of samples received early in the winter was low. This was attributed, at first, wholly to frost damage; but as the germination of samples tended to rise toward spring, it was seen that delayed germination was also a factor. In the tests conducted at 20°C., delayed germination occurred in association with a high proportion of "hard" or slowly permeable seeds, and a greater number of abnormal sprouts and decayed seed than might be found in a sample which had reached its full germinating capacity. Repeat tests did not consistently show an increase of germination with time of storage, but many gave erratic results. Germinating in a borrowed refrigerator at 10°C., resulted in satisfactory tests, but this equipment was inadequate to cope with the large number of samples received. Samples sent to the Winnipeg laboratory in April showed as much as 65% of delayed germination in tests made at 20°C. Samples germinating over 90% in May had given as low as 18% in early winter tests.

Review of Literature

In a twenty-year study of the longevity of seeds, Sifton (13), using oats from eastern Canada and the North-west Territories (Alberta), found a progressive increase in germination until the fifth year. He used alternating temperatures of 30° and 20°C., since found too high for northern grown oats. He found a difference in the longevity of seed produced in different years, and attributed the difference to temperature; seed growing in a cool wet year being more resistant to ageing than that produced in a warm dry year. He suggested that long lived seed in a given sample might produce plants with this factor for longevity in their genetic constitution.

Johnston (6), used University of Alberta stock of registered Victory oats in studies of the inheritance of delayed germination in reciprocal crosses between Avena sativa and Avena fatua. In similar crosses it had been shown by Aamodt, Manson, and Johnson (1), that segregation occurs for three grain types; sativa, intermediate and fatua, in the mono-hybrid ratio of 1:2:1. Johnson's genetical analysis of germination results obtained from the first three hybrid generations, indicated that germinability is inherited on the basis of three factors of more or less equal potency, one of which is linked with the factor for grain type. The mode of inheritance suggested by Johnson presumed the following parental genotypes:

Avena sativa (wA)(wA) A_2 A_2 A_3 A_3

Avena fatua (Wa)(Wa) a_2 a_2 a_3 a_3

At the time of testing, embryos having completely recessive genotypes were non-germinable, and those with one dominant allelomorph were non-germinable. Embryos with two dominant allelomorphs were to a very great extent germinable and those with more were germinable.

Johnson (6), found certain discrepancies in germination from theoretical ratios to be correlated with time of testing. This applied to the non-germinability of embryos with one, two, or more dominant allelomorphs. He inferred that shortly after harvest only embryos with six dominant allelomorphs A_1 A_1 A_2 A_2 A_3 A_3 are germinable. As time goes on, embryos with a progressively smaller number of dominant allelomorphs become germinable. The triple recessives (A. fatua) a_1 a_1 a_2 a_2 a_3 a_3 are the last to germinate.

Larsen, Harvey and Larsen (8), in Minnesota, studied the length of the dormant period of cereals cut in the soft dough, hard dough, and ripe stages. Samples were stored at 0°C., 7°C., and 14°C., tests being made at 20°C. with counts on the third, fifth and seventh day. When stored at 14°C., late oat varieties cut in either the hard dough or ripe stage, showed no period of after-ripening but those cut in the soft dough stage required six weeks. The three classes stored at 0°C., required from six weeks to more than two months. Late oats required a longer period than early oats and varieties also differed in length of their rest period. Among the varieties with the longest period was Victory 514. Cutting immature

or storage at low temperatures, increased the length of the rest period.

Delayed germination of cereals has been extensively studied in the seed testing stations of Denmark and Sweden. Dorph Peterson (12), refers to the failure of seed to germinate well until a certain period after harvest has elapsed, as due to the seed not being "germinating-ripe". In Denmark, wheat is usually "germinating-ripe" in October and November; but after moist cool summers the condition is delayed until sowing time or later in the case of barley and oats. Investigations showed that cutting off the distal ends of the seed removed the inhibiting cause and gave germination comparable with that of the seed when "germinating-ripe". As the cutting of the seed does not touch the embryo, the lack of "germinating-ripeness" was not considered due to a latent condition of the embryo, but to certain inhibitory effects of the seed coat. Samples of wheat, oats and barley harvested at progressive stages of maturity and germinated immediately and at monthly intervals, were fully "germinating-ripe" at the fourth test. Stored in the laboratory all samples were about normally dry by the second test, and most of them had reached full germinating capacity, but the germination speed was still low. In the case of the oats, the green ripe (glumes greenish, milky to tough dough) gave, as a rule, the largest germinating capacity and those fully ripe the smallest. When seeds were germinated at

three different temperatures, 18° to 20°C.; 14° to 16°C.; and 10° to 14 C., samples not after-ripened germinated best at the lowest temperature, while the "germinating-ripe" samples germinated almost equally at all three temperatures, but most rapidly at the highest.

Dorph Petersen gives evidence that the germination of seed exhibiting long delayed germination is favored in the field in the ensuing spring by low temperatures.

Hyde (5), discusses delayed germination in oats in New Zealand and his conclusions are in agreement with those of Peterson (12). He states that dormant oats germinate if they are first placed for about six days under moist conditions at a temperature within a few degrees of the freezing point of water. Thereafter they will continue to grow at higher temperatures in a normal way. Under warm conditions, 20° to 30°C., oats germinate completely only after the lapse of months and, furthermore, after a period of several days under these moist conditions, the seed loses its capacity to respond to the stimulus of low temperatures. Fully after-ripened oats, on the other hand, germinate within a wide range of temperature, from near freezing point to as high as 30°C., the optimum temperature being about 20°C. Hyde states that germination of non-after-ripened oats is of the same order in the field as in the laboratory at similar temperatures. It is the practice in the seed testing station at Palmerston, North., New Zealand, to prechill to find actual viability and test at

alternating temperatures from 30° to 20°C., to find the approximate rate of germination to be expected in the field if the seed is sown immediately. The time occupied by after-ripening varies from season to season. It proceeds slowly after a cool rainy summer. Artificial after-ripening may be brought about by drying or storage at 30°C. for about four weeks, but temperature, not moisture, is the most potent factor. Storage at low temperatures prolongs the period required for after-ripening. Prolonged storage at 30°C. adversely affects vitality.

The effect of frost upon seed oats in the field has been studied by Fryer (3) (4). He found that 2° to 3°F. of frost did not injure grain at any stage of maturity nor did 4° to 6°F. of frost (accompanied by heavy dew). Frosts of 5° to 8°F. occuring on consecutive nights injured oats in the early milk to dough stage but not those in the dough to dry mealy stage. Tests were made in November and December after frosts occuring in September and early October. In a later paper, Fryer (4) shows that while freezing probably does not destroy the semi-permeable membrane of oats and wheat, permeability to water is increased in frosted seeds. The less mature the wheat at time of exposure to frost the greater was the effect of frost on the kernel and the greater was the increase in speed of absorption.

Levitt and Scarth (9(have recently shown that increase in permeability of protoplasm is more closely correlated with

frost hardening (and drought resistance) than any other single mechanism in the frost hardening of living cells.

Booth (2) found that controlled temperatures from 31°F. to 27°F. for one to three hours had no effect on the germination of oats. Samples were cut in the field and exposed to frost as rapidly as they could be taken to the freezing chamber. Lewis and McCalla (10), using a similar method of controlled low temperatures with wheat, found that frost exposure greater than 4°F. reduced the percentage germination in direct proportion to the severity of the frost. Susceptibility to frost damage decreased with maturity and after the grain reached a 58% dry matter content, its susceptibility to damage by frost was nil or very slight.

Tedin and Garsner (14) in Sweden, studied naturally frosted oats in laboratory and field tests. Normal seedlings from frosted samples produced as high a percentage of normal plants in the field as did normal seedlings from undamaged samples. They concluded that "healthy" seed in a sample heavily damaged by frost, was equal to the seed of a completely healthy sample. Secondary kernels were found to be less damaged by frost than primary kernels and the difference increased with increasing severity of frost. Fusarium infection was found to increase with frost damage and secondary kernels were less affected by Fusarium than primary kernels. Johnson (6), in physiological studies of delayed germination in Avena fatua, found that the

secondary kernels exhibited longer dormancy than the primary kernels and that dormancy in the seeds increased from top to bottom of the panicle.

There appears to be no definite evidence available relative to the effect of frost upon delayed germination in seed oats. The evidence in the literature examined is definite with respect to the occurrence of prolonged dormancy in oats following rainy cool seasons. It is also definite with respect to the greater response of oats during the after-ripening period, to a lower temperature than 20°C.

Material and Methods

The bulk of the crop of seed oats produced in northern Alberta is made up of the varieties Victory and Banner. A large proportion of the lots of Victory are traceable to University of Alberta elite stocks and, for this reason, Victory oats secured from the University was used in this investigation.

The investigation was divided into two phases, in one of which pot grown oats were exposed to frost in a controlled temperature chamber, while in the other, oats were grown in field plots and were exposed throughout to naturally occurring conditions only.

Methods in the Controlled Temperature Experiment, 1936

In order to study the effect of frost upon oats at several stages of maturity, twelve hundred eight-inch pots were placed in a field cage. Two plants were grown in each pot, the main culms only being kept for treatment. Oats in groups of forty-five pots were exposed to frost at stages of maturity represented by 40%, 50%, and 60% dry matter content of the grain. Frost exposures used were 28°F., 24°F. and 20°F. For data on the effect of duration of frost, groups of fifteen pots were taken out of the refrigerator at 3, 6, and 9 hour intervals during each frost exposure. For studying the possibility of recovery from frost damage, each lot of fifteen pots was divided into three lots of five for harvest at the following periods after treatment, namely; immediately after, seven days after and fifteen days after. Pots to be harvested after seven days and fifteen days were returned to the field cage where untreated controls had been labelled and set aside. When the first freeze at 40% dry matter was finished, the treatment was repeated, using a group of pots which had been separated from the first group on account of their slightly later date of heading out. All treatments were so repeated. Plants were not hardened before frost nor slowly thawed out after frost. Dry matter determinations were made by individual tests of each of ten representative panicles. The oats from each panicle were separated from

the lemma and palea, weighed in small cans, then dried at 98°C. for one hour.

At time of harvest heads were loosely enclosed in cotton bags and stored in a shed. Oats were treated and harvested in August, threshed by hand in September, and forwarded to the Seed Laboratory in October, by freight. For the study of delayed germination, they were germinated in November, January, April and May. At the time of arrival at the laboratory, samples required for repeated tests were counted out. All samples were then stored out-of-doors. Samples of 50 seeds in duplicate were germinated at 18° to 20°C. in sand with counts at seven and twelve days.

Methods in Field Experiment 1936

Six plots were seeded every ten days from May 15th to July 4th, to form a latin square of thirty-six plots. Weather data were recorded by means of a hygro-thermograph and a soil thermograph housed in the plots. Composite samples were taken every two days from the end of pollination until the onset of frosty weather, after which all six plots of each seeding were sampled separately. Samples were cut with a sickle and stored in a shed. They were threshed with a hand thresher and electric fan in September. To show the differences that might occur between seed stored outside in farmers' bins during the winter, and samples stored in buildings, a

representative group of samples of each seeding were each divided into two for storage out-of-doors and in-doors. Samples were forwarded to the laboratory at Winnipeg in October, where all samples required for repeated tests were counted out, the samples then being stored under the required conditions. They were germinated in January, February, March and July. Samples of 100 seeds in duplicate were germinated at 18° to 20°C. in sand with counts at seven and twelve days.

Results of Controlled Temperature Experiment 1936

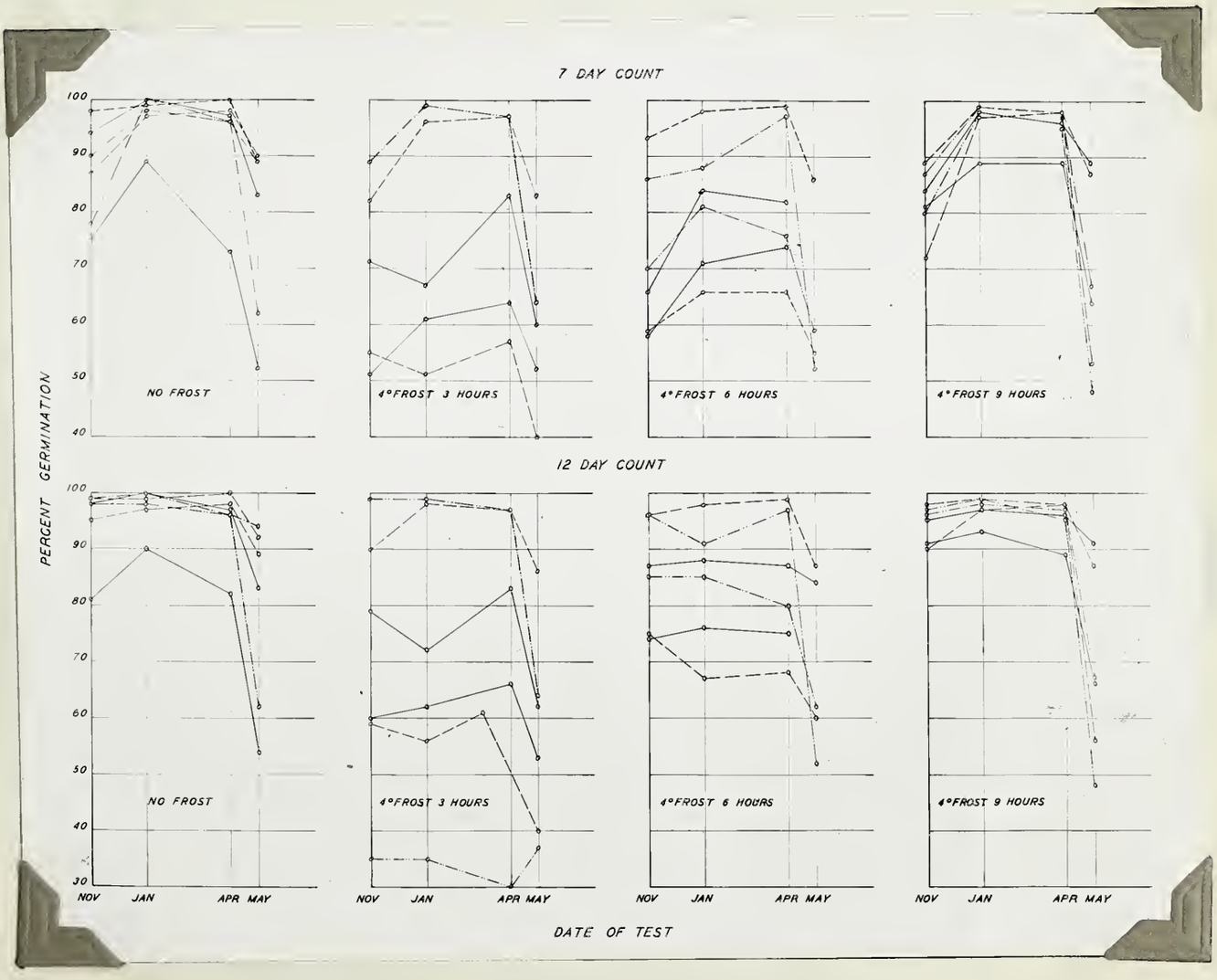
Oats grown in the pots produced large plants with about 90 spikelets per panicle. When panicles were stripped of chaff for dry matter determinations however, it was found that a high proportion of flowers had failed to develop after pollination, while a further number produced seed which hardened or dried prematurely. It was thought at the time that this was caused by the aphid Macrosiphon gramarium, but the condition has since been observed in field plots in which this aphid was not present. Some plants and some plots are more affected than others. The primary kernel is the one usually affected, the secondary seldom showing the effect. Occurring in association with a small proportion of watery kernels it is somewhat similar to a condition described

in corn by Mangelsdorf (11), but was not further studied in this investigation. The reduced yield made it necessary to employ 50 seeds in duplicate in germination tests and led to the occurrence of missing numbers in the May results.

Results of the frost exposures at 28°F. are shown graphically in Figures 1, 2 and 3. In these graphs the points were obtained by addition of the 50 seeds of each laboratory replicate. The results are thus shown on the basis of 100 seeds per test.

Figure 1.

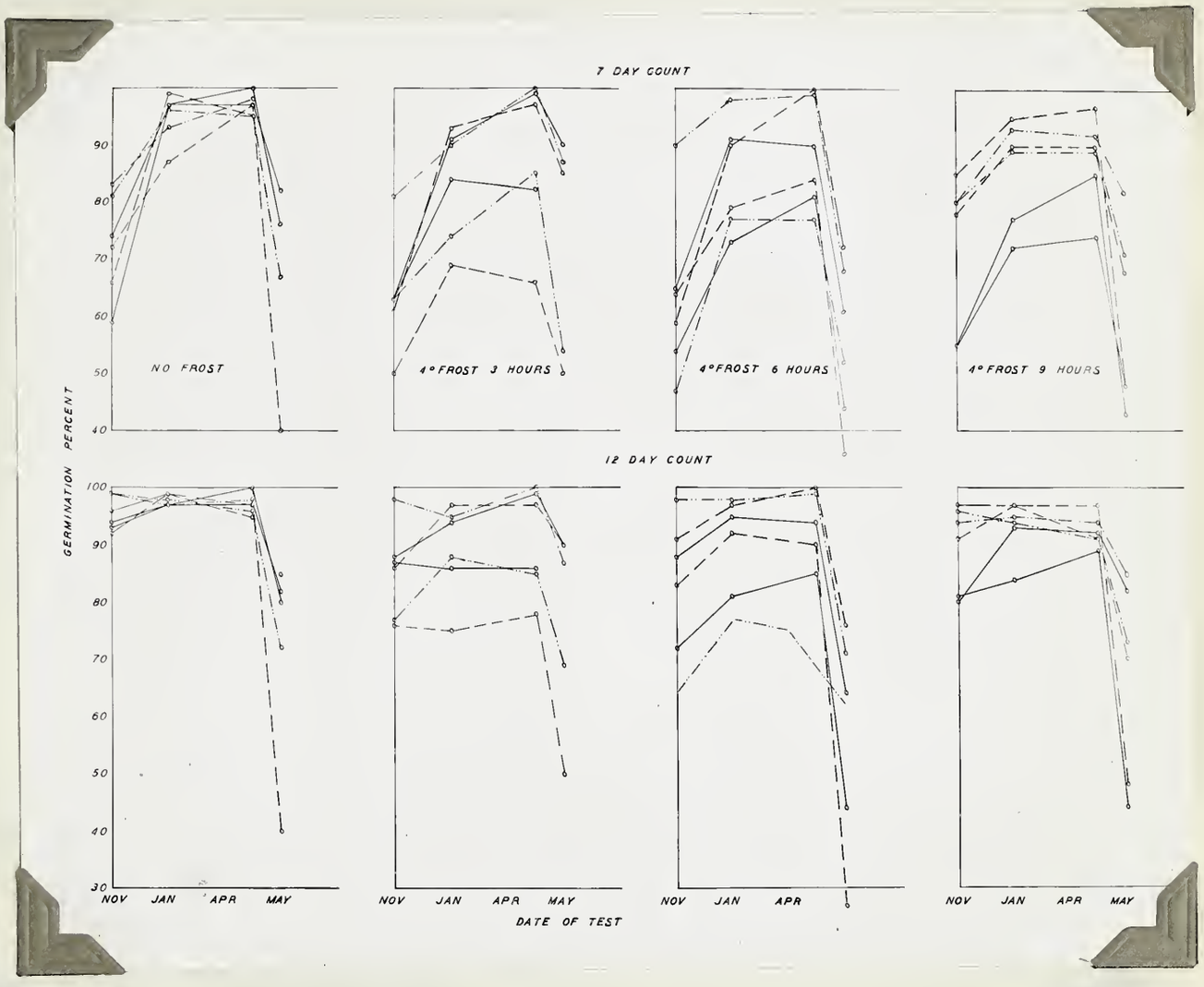
Germination of oats Frosted at a Stage of Maturity represented by 40% Dry Matter Content of the grain.



Legend shown on Figure 3 - Page 18.

Figure 2.

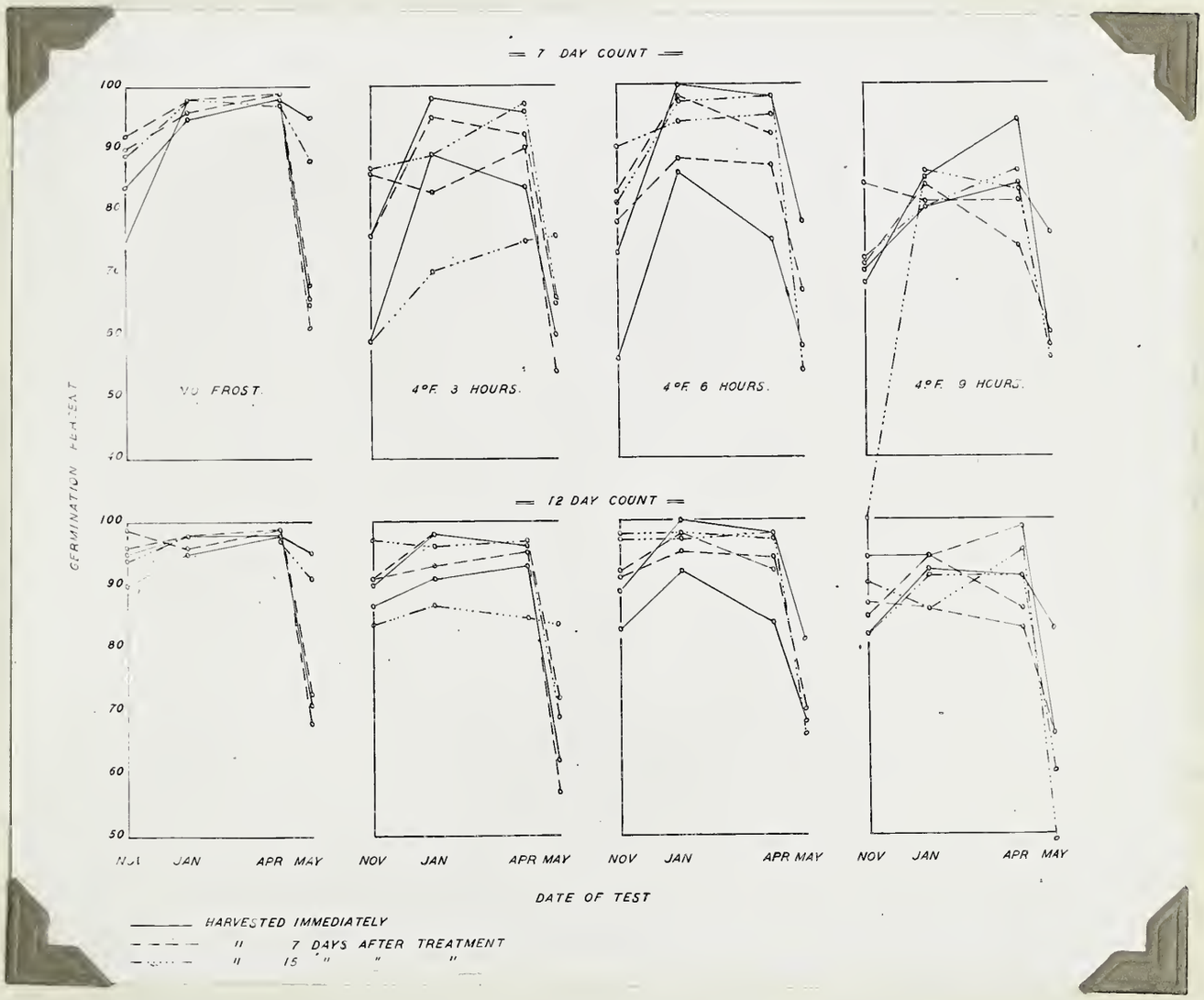
Germination of Oats Frosted at a Stage of Maturity represented by 50% Dry Matter content of the grain.



Legend shown on Figure 3 - Page 18.

Figure 3.

Germination of Oats Frosted at a Stage of Maturity represented by 60% Dry Matter Content of the grain.



The after-ripening period had apparently been passed or was just being concluded in November. This is seen more clearly in the seven day counts than in the twelve day counts. Owing to missing numbers in the May tests the graph is only indicative of what occurred in that month. The actual results are shown in Tables I and II, which include the complete figures for the 4^{o} freezes of material at 50% dry matter. Results from the freezes at other stages of maturity are included in the appendix as they do not differ essentially from those for 50% dry matter. Appendices 1, 2, 3, 4.

Differences in the effect of frost are due to irregularities of temperature occurring during certain runs. The large volume of radiating material, the small size of samples and sampling technique, were unsuited to the physical conditions obtaining in the refrigerator. Later work shows that 4^{o} of frost, Fahrenheit, is not lethal but a drop to 6^{o} causes serious damage to immature unhardened material. This drop occurred during some of the 4^{o} freezes and led to high treatment error. Analysis of variance shows that significant results are confined to dates of test only, and that conclusions with respect to the comparative effect of different frost treatments, cannot be drawn.

The important result shown is that both frosted and non-frosted samples, regardless of stage of maturity, exhibit the same sort of inverted "U" curve in the tests made.

TABLE I

Germination of Samples Treated at 50% Dry Matter Stage of Maturity. 7 Day Count.

Frost Exposure 4°F.	Harvest Days after Treatment	NOVEMBER A - B	JANUARY A - B	APRIL A - B	MAY A - B
None	0	35 - 39	48 - 49	50 - 50	38 - --
	0	27 - 32	48 - 49	50 - 47	41 - --
	7	30 - 36	49 - 50	46 - 49	37b- 45
	7	32 - 40	42 - 45	49 - 48	19b- 14
	15	42 - 41	45 - 48	49 - 49	-- - --
	15	43 - 38	46 - 50	49 - 46	29 - 38b
3 Hours	0	32 - 31	41 - 43	41 - 41	-- - --
	0	38 - 25	47 - 44	50 - 49	45 - 45b
	7	26 - 24	34 - 35	36 - 30	13 - 17b
	7	28 - 33	44 - 49	49 - 48	44 - 41
	15	28 - 35	36 - 38	43 - 42	25 - 29
	15	40 - 41	46 - 44	50 - 50	40 - 47
6 Hours	0	26 - 28	41 - 32	38 - 43	24 - 20
	0	36 - 29	46 - 45	44 - 46	35 - 26
	7	34 - 30	42 - 37	42 - 42	8 - 11b
	7	30 - 29	42 - 48	50 - 50	33 - 39b
	15	24 - 23	37 - 33	31 - 39	26 - --
	15	48 - 42	49 - 49	49 - 50	32 - 36
9 Hours	0	25 - 30	36 - 36	31 - 43	22 - 26
	0	27 - 28	39 - 38	40 - 45	20 - 23
	7	46 - 39	49 - 46	48 - 49	16 - 32b
	7	40 - 38	44 - 46	45 - 45	34 - --
	15	38 - 42	48 - 45	46 - 46	42 - 40b
	15	42 - 38	41 - 48	43 - 46	30 - 41b
	Average	-- 35.71	-- 43.48	-- 45.04	-- ----

Minimum Significant Difference Between Averages 4.09 ----

Coefficient of Variation			
11.9%	11.0%	8.9%	46.3%

b Browning noted.

A B Laboratory replicates.

TABLE 11

Germination of Samples Treated at 50% Dry Matter Stage of Maturity. 12 Day Count.

Frost Exposure 4°F.	Harvest Days after Treatment	NOVEMBER A - B	JANUARY A - B	APRIL A - B	MAY A - B
None	0	46 - 47	48 - 49	50 - 50	40 - --
	0	48 - 46	48 - 49	50 - 47	41 - --
	7	45 - 47	49 - 50	46 - 49	40 - 45
	7	48 - 48	49 - 50	49 - 48	22 - 18
	15	50 - 49	49 - 48	49 - 49	-- - --
	15	50 - 49	48 - 50	49 - 47	33 - 39
3 Hours	0	47 - 40	43 - 43	42 - 44	-- - --
	0	46 - 42	49 - 45	50 - 49	45 - 45
	7	38 - 38	38 - 37	39 - 39	29 - 21
	7	42 - 44	48 - 49	49 - 48	45 - 45
	15	37 - 40	44 - 44	43 - 42	25 - 29
	15	50 - 48	48 - 47	50 - 50	40 - 47
6 Hours	0	38 - 34	44 - 37	41 - 44	26 - 23
	0	45 - 43	48 - 47	46 - 48	35 - 29
	7	43 - 40	44 - 48	45 - 45	12 - 15
	7	47 - 44	49 - 48	50 - 50	35 - 41
	15	33 - 31	40 - 37	33 - 42	31 - --
	15	49 - 49	49 - 49	49 - 50	33 - 38
9 Hours	0	40 - 38	38 - 37	39 - 44	26 - 31
	0	37 - 44	41 - 43	42 - 46	21 - 23
	7	49 - 48	49 - 48	48 - 49	23 - 34
	7	49 - 42	49 - 48	45 - 46	35 - --
	15	46 - 48	48 - 47	46 - 48	43 - 42
	15	47 - 49	46 - 48	44 - 47	31 - 42
Average		--- 44.13 ---	45.92 ---	46.15 ---	----

F. 2.91 1% point 4.8 5% point 3.1

$$F. = \frac{\text{Dates Variance}}{\text{Residual}} = 2.91$$

The reduced germination in May was surprising. Its cause, whether residing in technique or in the seed, is not yet known. The increase of "browning" infection noted in May results, is not necessarily the cause but may be a secondary effect. Of interest is the high variation between duplicate laboratory tests when the seed is not responding to germinative conditions at 20°C. This may be seen by inspection of the tables, or from the average figures and their coefficients of variation shown at the bottom of Table I. . The significance of differences between these averages for dates of test was computed after subtraction of treatment variance from the total variance for each date of test. Owing to missing numbers in the May tests, the coefficients of variability for all dates were determined directly by addition of the columns under each date.

The 8° and 12° frosts were so severe that few samples produced any normal seedlings. The percentage of survival was so low that it was thought inadvisable to show the results. Tedin and Garsner (14) however, concluded that normal seedlings produced by heavily frosted seed were equal to the seed of unfrozen samples. As the 4° freezes had shown that seedlings from frosted seed behaved in a similar manner to those from the non-frosted controls, the normal seedlings, survivors from 8° and 12° frost exposures, were added together to find if they also behaved in this manner. The results are shown in Table III. Only samples allowing comparison of May results were used in the calculations.

TABLE III

Number of Normal Seedlings from Seed Surviving 8° and 12° Frost Exposures, Fahrenheit, for Three Hours or More.

8° Frost Exposure

Dry Matter	No. of Seeds	NOVEMBER	JANUARY	APRIL	MAY
40%	1500	20	19	17	11
50%	1500	85	94	105	53
60%	1500	341	404	420	232

12° Frost Exposure

Dry Matter	No. of Seeds	NOVEMBER	JANUARY	APRIL	MAY
40%	1800	0	0	0	0
50%	900	4	3	3	0
60%	1400	44	58	61	46

The number of seeds used in each test is shown in the table and if the groups with a survival of less than 2% are ignored, the remaining groups are seen to vary from November to May in the same manner as the unfrozen controls.

The figures in Table III show a progressive increase of germination until April and if this is not due to error of sampling, it might suggest that heavily frosted seed after-ripens more slowly than non-frosted seed. It is likely that this whole experiment can be reviewed by a method of analysis

used by Tedin and Garsner (14) in their studies of oats showing various degrees of frost damage, and the effects registered by primary and secondary kernels. It seems inadvisable to discuss the subject of analysis however, until certain graphs showing the kind of trends to be expected in repeated germination tests have been presented in the next section of the paper.

Results of Field Experiment 1936

Samples from the field plots were germinated for the first time in January. Those from the first four seedings had finished after-ripening by this time and all but the most immature germinated nearly 100%. As most samples germinated fully in seven days during the months of January, February and March, they were dropped from the May tests to save work in the laboratory. When the May tests of the artificially frosted material gave low results, it was decided to retest the field samples. This, however, was unavoidably delayed until July. The fifth seeding alone of the six (the sixth did not pollinate) showed delayed germination as measured by increase in percentage germination with time. As its germination was low in winter tests on account of immaturity or frost damage plus delayed germination, it was germinated in both May and July.

It seems unnecessary to illustrate the difference between the first four seedings and the fifth by showing all the tables. The first and second seeding results are fairly typical and are shown in Tables IV and V, in which the two laboratory tests of each determination are given to show variation between laboratory replicates in July tests.

TABLE IV

Germination of Field Plot Samples Taken at Successive Intervals from End of Flowering 1936

First Seeding - May 15 to August 12.

Date Cut	Days after Poll'.*	Wght. in Grams	PERCENTAGE GERMINATION JANUARY 7 Day	12 Day	FEBRUARY 7 Day	12 Day	MARCH 7 Day	12 Day	MAY 7 Day	12 Day	JULY 7 Day	12 Day	18 Day
	0												
	2												
	4												
Jul. 25	6	17.2	72	96	78	97	86	92	80	90	--	--	--
" 27	8	19.3	85	97	85	100	94	96			1	89	89
			79	93	87	98	89	95			1	66	82
" 29	10	22.2	98	--	98	--	98	--			2	67	94
			99	--	99	--	96	--			0	59	95
Aug. 2	14	24.3	99	--	100	--	98	--			16	99	--
			94	--	99	--	98	--			5	71	92
" 4	16	27.1	95	--	99	--	98	--			1	97	--
			100	--	98	--	96	--			12	96	--
" 6	18	27.0	99	--	100	--	99	--			99	--	--
			100	--	99	--	98	--			88	89	89*B
" 8	20	27.5	99	--	100	--	98	--			2	81	91
			98	--	99	--	99	--			10	79	97
" 10	22	27.8	99	--	100	--	99	--			3	59	96
			99	--	100	--	99	--			1	68	97
" 12	24	27.3	100	--	98	--	98	--			2	91	91
			100	--	98	--	99	--			1	94	94

* Germinated July 5th, others July 9th.

B Browning noted.

‡ Days from end of Pollination.

TABLE V

Germination of Field Plot Samples Taken at Successive Intervals from End of Flowering 1936

Second Seeding - May 26 - August 19.

Date Cut	Days after Poll'.**	Wght. in Grams	PERCENTAGE GERMINATION JANUARY 7 Day	JANUARY 12 Day	FEBRUARY 7 Day	FEBRUARY 12 Day	MARCH 7 Day	MARCH 12 Day	MAY 7 Day	MAY 12 Day	JULY 7 Day	JULY 12 Day	JULY 18 Day
Jul.25	0	12.1	54	46	--	--	--	--	--	--	--	--	--
" "			56	50	--	--	--	--	--	--	--	--	--
Jul.27	2	12.1	52	57	55	55	--	--	--	--	--	--	--
" "			56	62	51	63	--	--	--	--	--	--	--
Jul.29	4	15.8	69	91	77	92	79	87	55	57b	36	--	--b
" "			75	91	83	99	73	87	70	71b	54	49	54b
Jul.31	6	17.3	78	97	89	96	90	98			55	94	--
" "			91	97	84	95	88	93			11	82	--
Aug. 2	8	18.5	78	96	88	98	77	88	59	62b	8	86	--
" "			83	97	83	97	85	92	81	84b	25	90	--
Aug. 4	10	20.3	79	94	99	--	92	96			15	97	--
" "			81	95	98	--	91	94			13	98	--
Aug. 6	12	25.1	99	--	100	--	98	--			95	95	--*
" "			97	--	99	--	100	--			85	87b	--*
Aug. 8	14	26.2	99	--	99	--	100	--			10	98	--
" "			99	--	100	--	100	--			12	95	--
Aug.10	16	27.6	99	--	99	--	100	--			82	97	--
" "			99	--	100	--	100	--			20	97	--
Aug.12	18	29.1	99	--	100	--	98	--			2	63	96
" "			99	--	100	--	99	--			1	68	98
Aug.19	25	30.2	100	--	99	--	100	--			98	--	--
" "			100	--	99	--	100	--			5	70	99**

* Germinated July 5th, others July 9th.

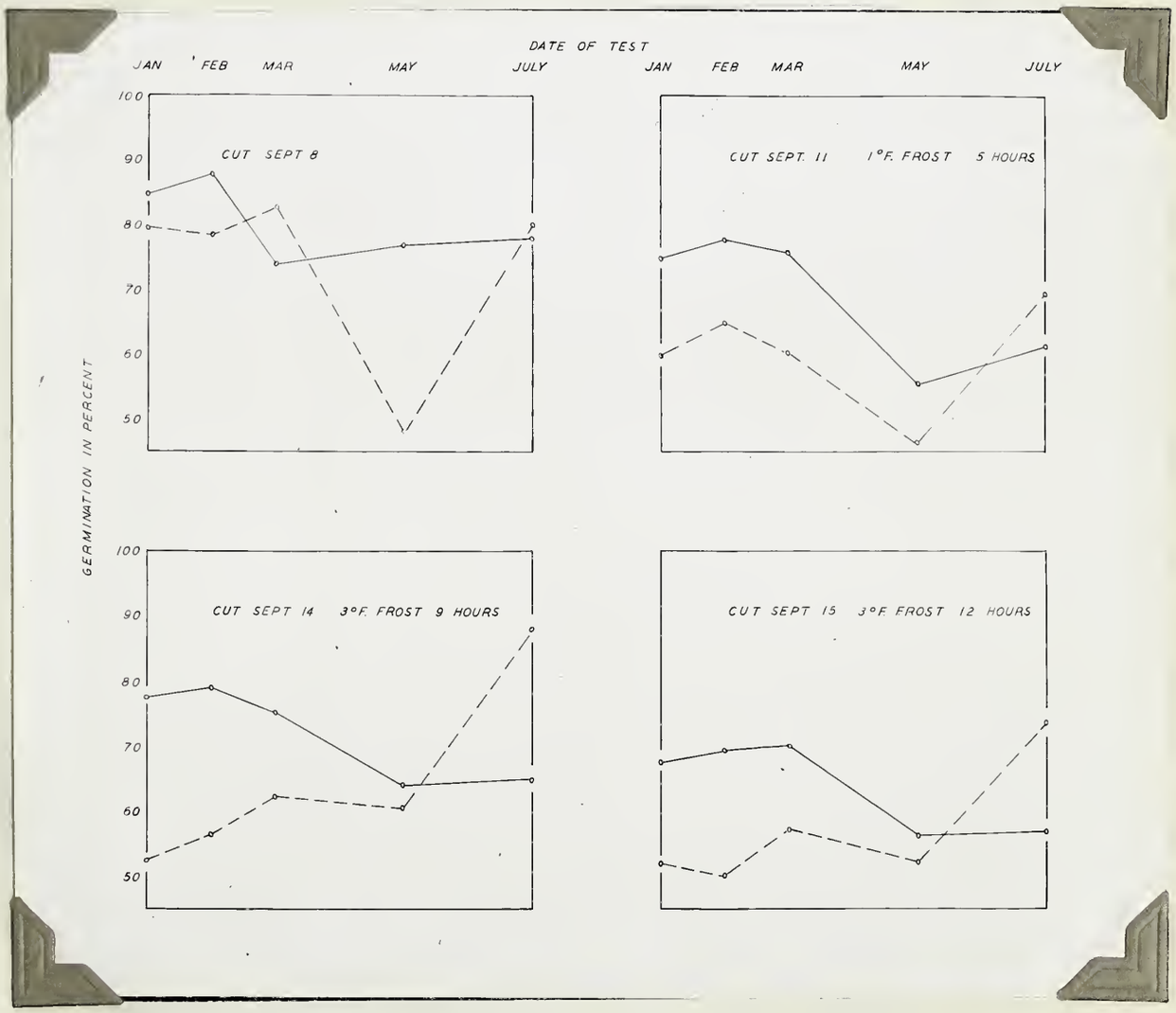
b Browning noted.

** Days from end of Pollination.

Figures 4 and 4 A show the results obtained from the fifth seeding samples produced in September. These took twelve days to germinate in all tests.

Figure 4

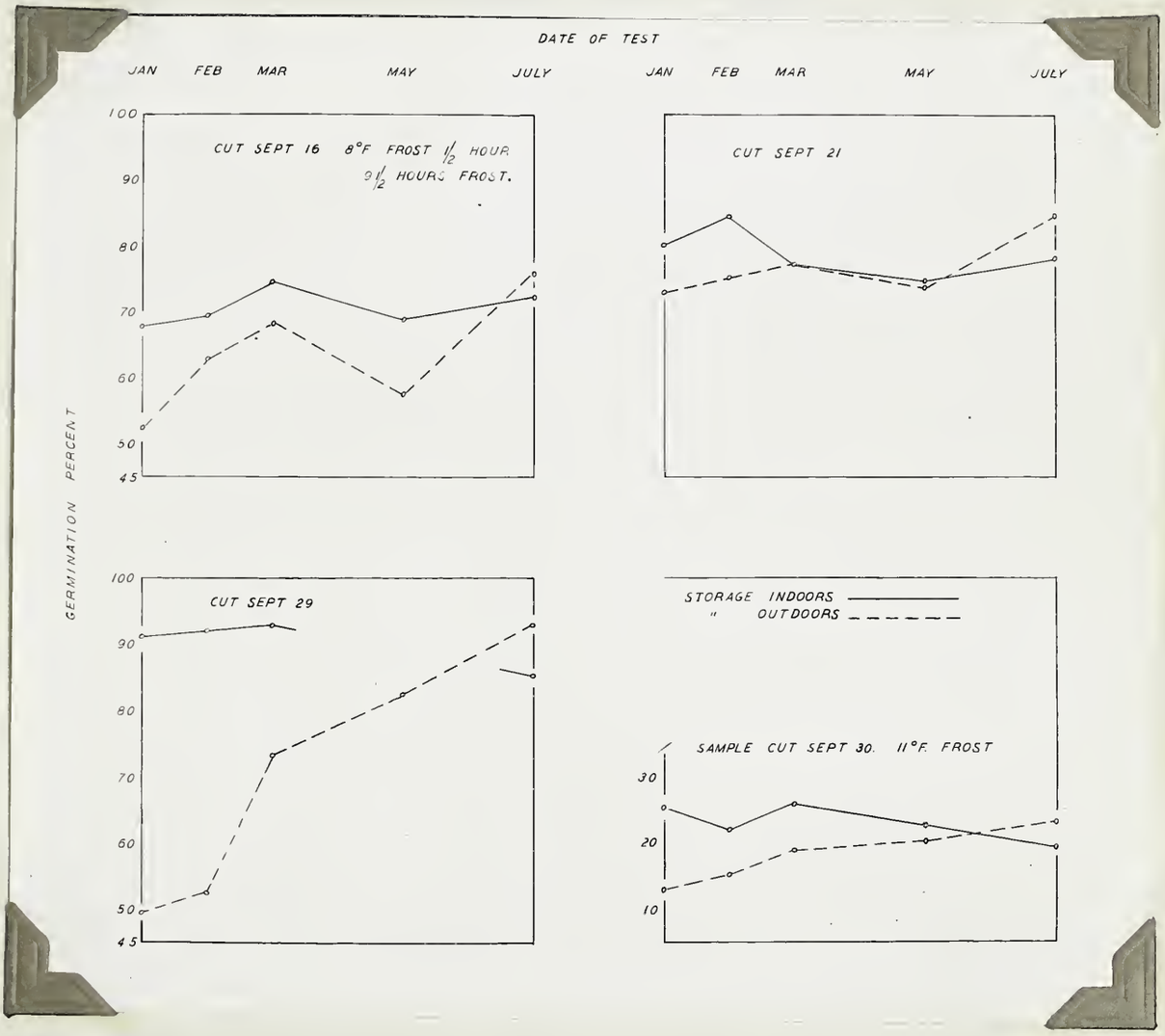
Germination of Fifth Seeding Samples Stored In-doors and Out-doors, Showing Delayed Germination and Resistance to Frost.



Legend shown on Figure 4 A - Page 29.

Figure 4 A

Germination of Fifth Seeding Samples Stored In-doors and Out-doors, Showing Delayed Germination and Resistance to Frost.



The actual results of the samples taken September 29th are given in Table VI. Only five plots of this seeding were suitable for sampling.

TABLE VI

Fifth Seeding Cut September 29th
Percentage Germination of Samples in Duplicate - 12 Day Counts

Samples Stored Inside

Plot No.	DATE OF TEST: JANUARY 9 A	JANUARY 9 B	FEBRUARY 9 A	FEBRUARY 9 B	MARCH 13 A	MARCH 13 B	MAY 14 A	MAY 14 B	JULY 19-24 A	JULY 19-24 B
11	91	97	93	92	88	97	83	75	84	79
18	95	96	96	92	84	97	91	86	83	84
20	90	71	92	90	98	95	--	--	89	92
28	96	90	93	88	94	91	--	--	80	89
31	91	94	93	93	91	94	--	--	80	82
Average	91.1		92.2		92.9		(83.75)		84.2	

Samples Stored Outside

Plot No.	JANUARY 6 A	JANUARY 6 B	FEBRUARY 5 A	FEBRUARY 5 B	MARCH 10 A	MARCH 10 B	MAY 13 A	MAY 13 B	JULY 14-16 A	JULY 14-16 B
11	42	54	65	48	80	62	57	77	94	88
18	49	56	48	56	72	73	84	86	94	95
20	49	49	58	58	75	68	94	96	94	87
28	50	52	49	55	85	78	96	86	95	97
31	47	48	48	45	68	72	70	77	93	94
Average	49.6		53.0		73.3		82.3		93.1	

A B = Laboratory Replicates.

Delayed germination in the outside stored seed is pronounced, but because the inside stored seed was germinating about its maximum in January, as were samples from earlier seedings, the dormancy could not be regarded as of any greater degree than that of earlier seedings. It can only be suggested that the dormancy was of longer duration in outside stored seed because of later production of the seed and preservation of the condition by low storage temperatures. This theory will be referred to again on P.37.

The sampling technique was not sufficiently refined to enable comparison of samples with respect to the level of germination after frost. The oats were remarkable for having withstood, while immature, many hours of hard frosts. From the evidence provided by the controlled temperature experiments, one might regard the normal seedlings produced in laboratory tests of these samples as arising from undamaged seed behaving in a normal way. (Tables I, II, III.) These assumptions are tested in the experiments of 1937, in which the technique of sampling was improved.

Aberrant May and July tests in the 1936 results may be attributed to differences in technique on different dates, to changes occurring in the seed from time to time, or to some change in environmental conditions acting independently of technique.

In Table VI the difference in July between the germination of the five samples stored outside and the five stored

inside, is highly significant, as shown by the analysis of variance or by comparison of means of small samples. The average of the inside stored is 84.2% germination and that of the outside stored seed is 93.1%. The probability of this difference being due to random errors of sampling, by comparison of means of small samples, is less than 0.0001. Analysis of variance made upon the two treatments morecver, shows a highly significant difference. The variance for treatment over residual, gives an F. value of 24.6, whereas a value of 9.07 only would be evidence of the difference being attributable to random sampling once in one hundred times.

In the results from outside and inside-stored samples of the four seedings preceding the fifth, the position is reversed, the inside-stored seed being higher in germination in July, than the outside-stored seed. See Tables VII, VIII, and IX. In these tables, to save space, the seed analysts official figures are given instead of the duplicate results. Complete figures are given in appendices 7, 8, 9.

Note:

Page 33 is omitted as a discussion of the dispersion of various groups in Table VI was dropped, pending examination of the value of a recommended Chi-square test.

TABLE VII

Inside and Outside Storage - Field Samples

First Seeding - May 15 to August 12.

Date Cut	Days after Poll'. ø	Storage	PERCENTAGE GERMINATION JANUARY 7 Day	JANUARY 12 Day	FEBRUARY 7 Day	FEBRUARY 12 Day	MARCH 7 Day	MARCH 12 Day	MAY 7 Day	MAY 12 Day	JULY 7 Day	JULY 12 Day	JULY 18 Day	
Jul.31	12	In	99	--	85	88	99	--	--	--	98	--	--	***
		Out	99	--	99	--	93	95	--	--	1	61	96	*
Aug. 5	17	In	99	--	99	--	99	--	--	--	99	--	--	**
		Out	99	--	98	--	99	--	--	--	7	55	98	*
Aug.12	24	In	99	--	99	--	99	--	--	--	97	--	--	**
		Out	100	--	98	--	99	--	--	--	2	93	--	*

Second Seeding - May 26 to August 19.

Aug. 5	10	In	99	--	99	--	98	--	--	--	91	97	--	**
		Out	99	--	99	--	98	--	--	--	91	97	--	*
Aug.12	17	In	100	--	99	--	99	--	--	--	99	--	--	**
		Out	99	--	100	--	99	--	--	--	2	65	97	*
Aug.19	24	In	99	--	100	--	99	--	--	--	99	--	--	**
		Out	100	--	99	--	100	--	--	--	51	99	--	*

* Tested 9th of July.
** Tested 23rd of July. *** Tested 22nd of July.

The inside-stored seed has the greater vigor of germination in July in these tables. The dates of test correspond with those of fifth seeding samples stored inside the germination of which, in contrast with the above, was lower than that of outside-stored seed.

ø Days from end of Pollination.

TABLE VIII

Inside and Outside Storage - Field Samples

Third Seeding - June 4th to September 6th.

Date Cut	Days ø after Poll'.	Stor-age	PERCENTAGE GERMINATION JANUARY 7 Day	JANUARY 12 Day	FEBRUARY 7 Day	FEBRUARY 12 Day	MARCH 7 Day	MARCH 12 Day	MAY 7 Day	MAY 12 Day	JULY 7 Day	JULY 12 Day	JULY 18 Day	
Aug.12	10	In	97	--	92-94		98	--	--	--	97	--	--	oo
		Out	98	--	99	--	99	--	--	--	73-98	--		*
Aug.19	17	In	99	--	99	--	99	--	--	--	99	--	--	oo
		Out	98	--	98	--	99	--	--	--	5-87-98			*
Aug.26	24	In	99	--	99	--	99	--	--	--	98,	--	--	oo
		Out	99	--	99	--	99	--	--	--	21-99	--		*
Sept.1	29	In	99	--	99	--	99	--	--	--	99	--	--	oo
		Out	99	--	99	--	99	--	--	--	85 100	-		**
Sept.4	33	In	98	--	99	--	99	--	--	--	99	--	--	oo
		Out	99	--	99	--	99	--	--	--	27-98	--		*

Fourth Seeding - June 13th to September 21st.

Aug.19	11	In	93-97		89-97		92-95		--	--	87-97	--		oo
		Out	92-94		95-96		96	--	--	--	35-96	--		**
Aug.26	18	In	94-99		97	--	98	--	--	--	69-75	--		oo
		Out	78-89		90-97		89-95		--	--	33-97	--		*
Sept.1	23	In	99	--	94-95		97	--	--	--	95-97	--		oo
		Out	92-97		91-95		97	--	--	--	97	--	--	**
Sept.5	27	In	98	--	99	--	96	--	--	--	91-97	--		++
		Out	98	--	98	--	98	--	--	--	46-97	--		**
Sept.8	30	In	98	--	99	--	97	--	--	--	95	--	--	o
		Out	98	--	99	--	97	--	--	--	64-98	--		**
Sept.11	33	In	98	--	98	--	99	--	--	--	97	--	--	o
		Out	98	--	98	--	98	--	--	--	65-97	--		+

* Tested July 9th. + Tested July 15th. o Tested July 19th.
** Tested July 10th. ++ Tested July 16th. oo Tested July 23rd.
ø Days from end of Pollination.

TABLE IX

Inside and Outside Storage - Field Samples

Fifth Seeding - June 24th Seeded

Date Cut	Days after Poll.ø	Stor-age	PERCENTAGE GERMINATION JANUARY 12 Day	FEBRUARY 12 Day	MARCH 12 Day	MAY 12 Day	JULY 12 Day	Date of July Test.
Sept.8	5	In	85.0	87.7	74.0	77.0	78.3	19th
		Out	80.0	78.7	83.0	48.3	80.0	14th
Sept.11	8	In	75.0	78.2	71.4	55.6	61.5	19th
		Out	60.2	65.4	60.4	46.4	69.5	15th
Sept.14	11	In	78.4	79.5	75.2	64.0	64.6	20th
		Out	52.4	56.4	62.2	55.4	77.8	15th
Sept.15	12	In	68.4	69.6	70.6	56.4	56.8	21st
		Out	52.0	50.2	57.6	52.4	73.8	15th
Sept.16	13	In-	77.0	79.0	74.8	69.4	72.4	21st
		Out	52.6	63.0	68.8	57.6	76.2	15th
Sept.21	18	In	80.4	84.6	77.6	75.8	78.6	21st
		Out	73.6	75.6	77.6	75.2	85.0	16th
Sept.29	26	In	91.4	92.4	93.4	--	85.4	24th
		Out	49.8	52.8	73.6	82.4	93.4	16th
Sept.30	27	In	25.8	22.0	27.0	22.8	19.6	24th
		Out	13.0	15.6	19.0	20.2	23.2	16th

The results in this table are shown in Figure 4. It may be noted that samples taken ten to twelve days after pollination, in the first three seedings, germinated completely in seven days. It took about twenty days to produce such samples in the fourth seeding while in the fifth, no such samples were produced.

ø Days from end of Pollination.

In the foregoing tables, the figures cannot be compared in a satisfactory way, comparable samples not being germinated on the same date, and many results showing slower speed of germination rather than a reduced total germination. It is clear, however, that tests of outside-stored seed not showing delayed germination gave, during the winter months, more consistent results than did tests in May or July. It is hoped that results from 1937 experiments will afford a better view of this behaviour.

Production of Oats Showing Delayed Germination in 1937.

Sufficient results are now available to illustrate the validity of the theory with respect to the production of oats showing delayed germination, developed after examination of Table VI. Page 31.

In 1937, plots were sown every ten days from May 15th as in 1936. At heading time of each seeding the uppermost leaf blade of plants heading at the same time was clipped with scissors, and marked plants only were sampled for both dry matter determination and germination tests. Duplicate plots were sampled. Samples were taken every three days from the end of pollination, dried in a shed and sent to the laboratory for germination one week after harvest, three weeks after and five weeks after. Later tests are to be made but results at hand are those for the first three dates of test. The samples were germinated at 18° to 20°C. in quadruplicate tests of 100

seeds. As a check, 100 seeds in duplicate, were tested by germinating at 15°C. for the first six days and at 20°C. for the last six days. In the tests at 20°C. counts throughout were made at six and twelve days. In the "pre-chill"test a final count only was made.

Figures 6 and 7 show results obtained from the first seeding and the fourth seeding. The former matured in relatively warm weather before frost, the latter in the colder weather of September ending in frost. Both were allowed to stand in the field, the former until thoroughly dry, the latter until the occurrence of a frost at 10°F. occurring seventeen days after the oats could have been cut at a 58% dry matter content, when all kernels had turned yellow.

Germination of Field Plot Samples Taken at Progressive Stages of Maturity and Germinated at One-Week, Three-Weeks and Five-Weeks After Harvest. 1937.

Figure 6 - First Seeding

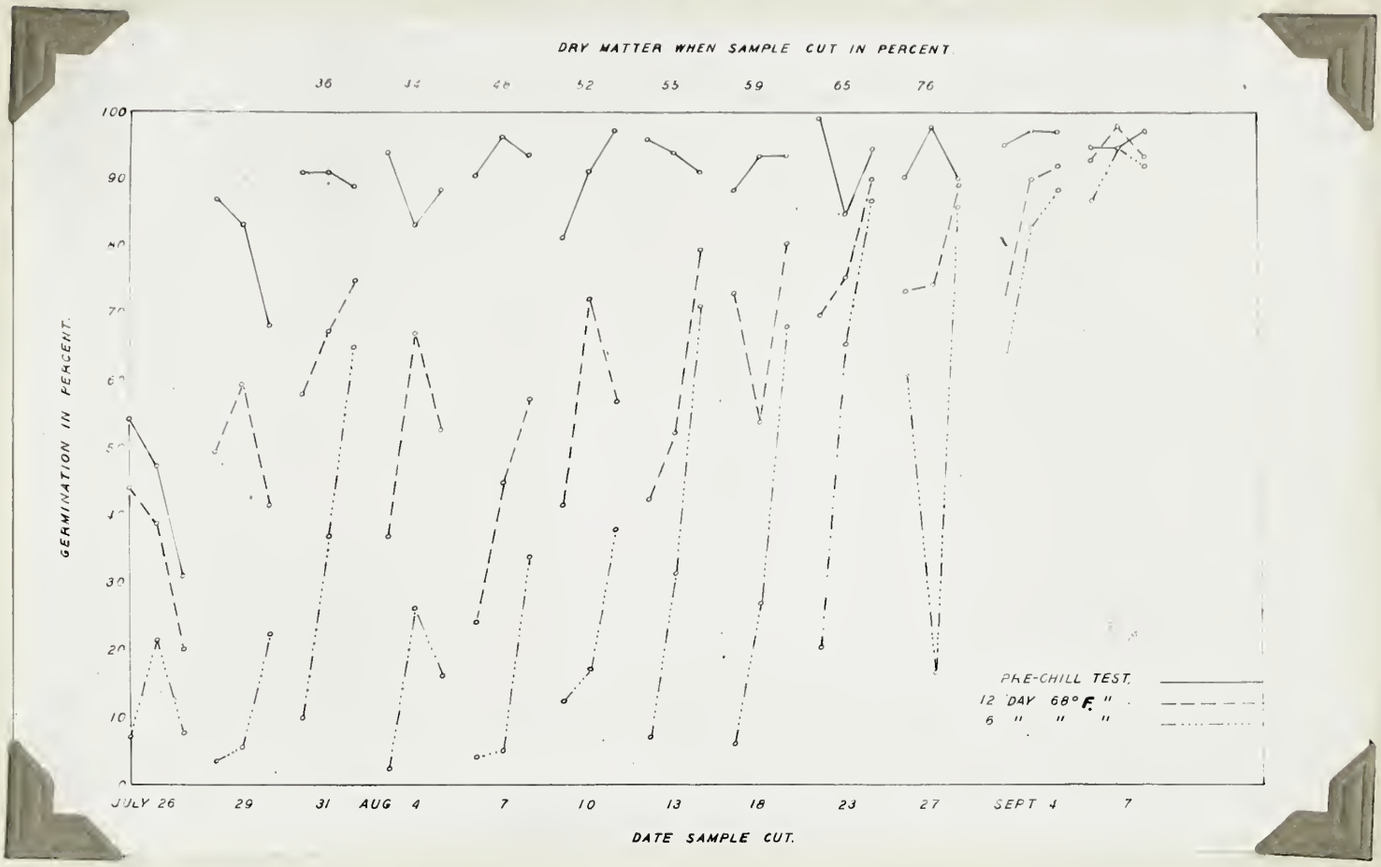
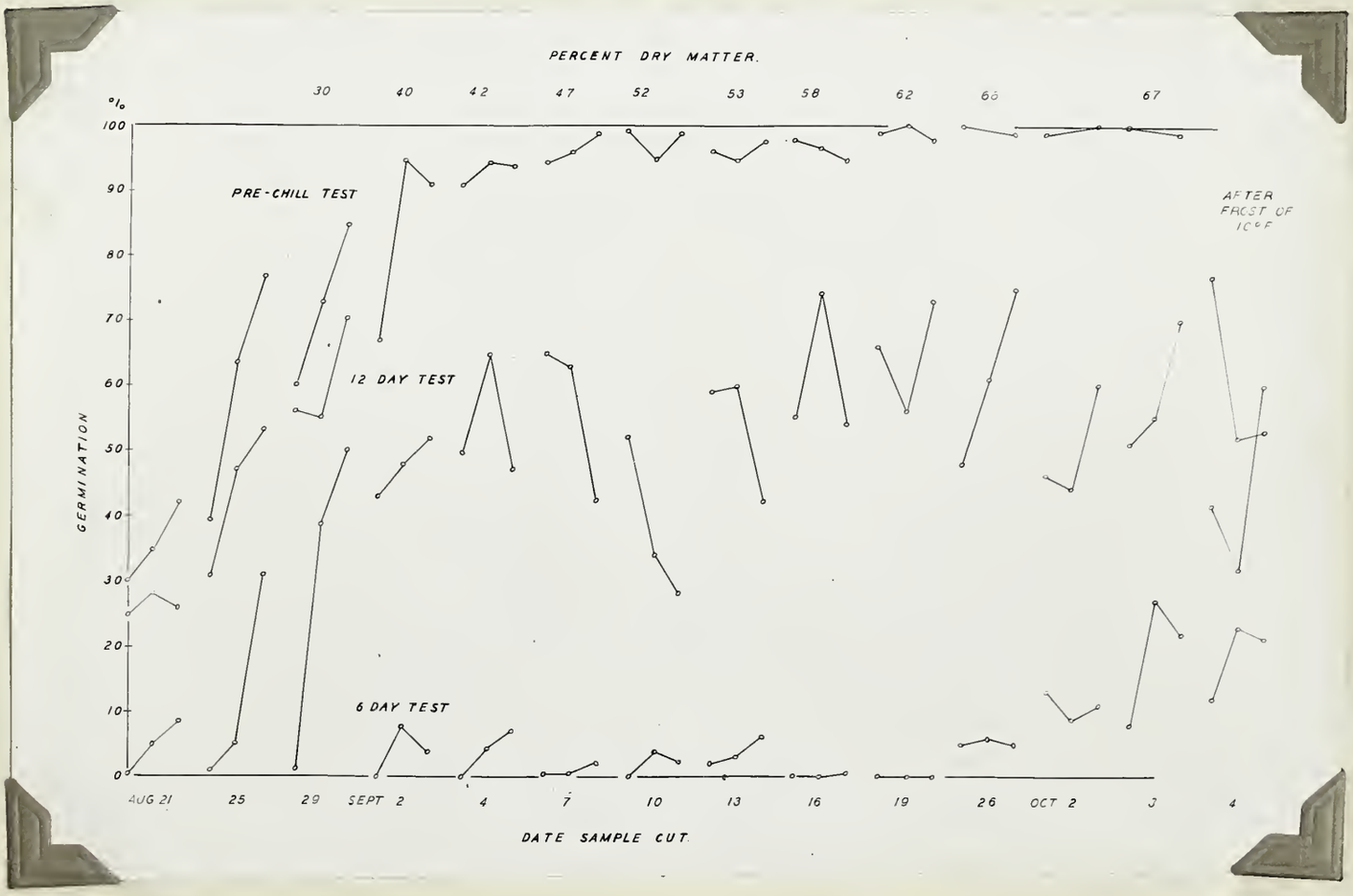


Figure 7 - Fourth Seeding



The figures show that seed from both early and late plots, germinates best at the lower temperature, and that the earlier harvested seed rapidly reaches a stage at which it germinates readily at both temperatures. The germination of the late harvested seed is low at 20°C. The figures clearly show the reason why seed, harvested at the usual time, gives satisfactory results in tests made at 20°C., and why later harvested seed gives unsatisfactory results for some time in such tests. The former passes its so-called after-ripening period before it is sent to the laboratory, the latter does not.

In 1937 all seedings but the first show a fairly marked delayed germination in tests at 20°C. for the first three dates of test. This requires explanation upon the basis of the crop history, which will not be made until completion of the 1937 results. It is thought that it does not alter the validity of the simple conclusion reached with respect to the production of seed showing delayed germination. The six-day counts in tests of all seedings, show a progressive decrease from that of the first seeding to that of the fourth in which it will be noted the six-day count lies along the zero line in contrast with its rapid rise in the first seeding.

The slow loss of moisture in the fourth seeding contrasted with that of the first, may be seen by comparing

the maturing periods of the two seedings and their respective rates of loss of moisture.

With respect to the subject of loss of moisture, weather records for 1935, 1936 and 1937 show that September weeks have an average temperature between 50°F. and 60°F. In the last half of the month the average may fall to as low as 51°F. These averages were measured by weighted means of hours between 20° and 30°, 30° and 40°, etc. from thermograph records. A lower average temperature is only prevented by the flattening of the curve of night temperature by dew fall. The grain is bathed in dew from 7 P.M. to 10 or 11 A.M. the following morning. A combination of high humidity and low temperature thus confines maturing or drying to an hour or so about mid-day.

When humidity is low, radiation is so high after sundown, that frost ensues. In view of the usual retention of moisture by damp grain throughout the winter, it seems likely that grain harvested in September when tough or damp, retains a high proportion of its water content until the onset of higher temperatures. The probable differences, therefore, between seed represented in figure 5 and that in figure 6, would be, by the time of the third test, a higher moisture content in the latter, together with less progress toward the shrunken stage and a potentially more active respiratory substrate.

The probable importance of respiration as a cause of differences between the two seedings and the two kinds of test, is shown in the figures by the sharp drop in germination occur-

ring at about 40% dry matter. This marks a period of rapid development with high respiration in the embryo and the beginning of the color change in the seed.

The rise which follows the drop in germination appears from the figures, to be correlated with loss of moisture which proceeded more or less normally in the first seeding and which was impeded in the fourth as explained.

The higher germination preceding the drop appears to be associated with weakness shown by the lower "pre-chill" total compared with that of later samples. It is higher perhaps, due to the immature stage of the grain and the absence of the restrictions placed upon permeation of water by the seed coat membranes which cutinize and suberize at a later period of development. It is exhibited by normal spindly seedlings.

The difference between the two tests is mainly attributable to ungerminated seeds. It is not accounted for in 18-day counts of the seed germinated at 68°F. A few seedlings are abnormal, and a few germinate in eighteen days in the 68° test. The remainder are either attacked by fungus or remain impermeable and ungerminated. In the "pre-chill" test all these classes produce almost entirely normal seedlings in the 12-day count. Root growth is stimulated and plants emerge vigorously. Complete examination of changes in number of abnormal, diseased and impermeable seeds with time of storage has not yet been made.

The drop in germination, recorded by the "pre-chill" test after 10° of frost, occurs also in the controlled temperature

experiments of 1937, in all cases where frost exposure reduced germination. More repeated tests in both experiments are required before its significance will be known.

Discussion

The investigation had as its object the production of seed exhibiting delayed germination and determination of the conditions under which the phenomenon occurred, so that material for laboratory studies could be produced at will.

The work was started under the handicap of an idea partly preconceived and partly the result of statements found in literature reviewed, that delayed germination in Avena sativa was an unusual phenomenon occurring in certain rainy cool seasons. Literature most pertinent to the subject, was not available until after commencement of the investigation. In the two years work, however, oats showing delayed germination were produced in plots maturing late and stored outside. It was assumed that a temporary failure to respond to germinative conditions at 20°C. was normal behavior, and that in oats matured and stored at low temperatures this characteristic was not more pronounced but was preserved longer. The results of 1937 work now becoming available, show the characteristics of the phenomenon even more clearly than do results of 1936. They demonstrate that oats of both early and late maturity, germinate fully at a lower temperature, regardless of the stage of after-

ripening gauged by their germination at 20°C.

Stiles (13 A) has shown that such a process, involving a changing response to temperature, is the result of the action of two forces, one a stimulus, the other an inhibition of enzyme activity. In seed, the course of these can probably be measured by change in the respiratory coefficient or, if anaerobic respiration is involved, the I/N ratio. These, however, would register an effect rather than explain the causes as a germination test registers an effect without explaining its causes. They would, however, provide evidence of an oxygen deficiency if that were a cause.

A study of the causes involves examination of the anatomy, ontogeny, and physiology of the oat and a knowledge of its behaviour under different circumstances. The complete results of 1937 experiments may therefore be prefaced with a review of the subject from this standpoint. In the present paper, the problem is brought to the point at which the physiology rather than production of delayed germination, becomes of importance. The effects produced by frost are not yet conclusive and data relative to this and the value of the pre-chill test for germination of frosted oats is still to be obtained from later figures. The possibility of depression of viability in spring or summer months also awaits confirmation from later results.

The figures show trends invalidating the general application of analysis of variance the value of which, will be confined to comparisons between the same samples on different dates,

between equivalent samples of different seedings on equivalent dates, and between the two types of test of any sample or its equivalent in another seeding.

- If later results do not change conclusions reached with regard to the production of oats showing delayed germination, it would appear that five graphs representing the five seedings sampled in 1937, would give a complete picture of the factors involved especially if accompanied by a graph of weather observations in the three seasons under examination during the course of this investigation.

ACKNOWLEDGMENT

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Appendix I

CONTROLLED TEMPERATURE EXPERIMENT
Germination of Samples Treated at 40% Dry Matter Stage of Maturity. 7 Day Count.

Frost Exposure 4°F.	Harvest Days after Treatment	NOVEMBER A - B	JANUARY A - B	APRIL A - B	MAY A - B
None	0	47 - 47	50 - 50	49 - 48	38b-45b
	0	37 - 38,	48 - 41	28b-45	27 - --
	7	50 - 48	49 - 50	50 - 50	47 - 42
	7	42 - 45	49 - 48	48 - 50	45 - --
	15	45 - 43	50 - 50	48 - 48	45 - 44
	15	45 - 45	50 - 48	48 - 48	0 - --
3 Hours	0	23 - 28	26 - 35	27 - 37	25 - 27
	0	37 - 34	34 - 33	42 - 41	22b- 38b
	7	29 - 26	24 - 27	28 - 29	0 - --
	7	42 - 40	46 - 50	48 - 49	40 - 43b
	15	12 - 10	15 - 11	10 - 16	18 - 11
	15	44 - 45	49 - 50	48 - 49	31 - 23
6 Hours	0	29 - 29	36 - 35	39 - 35	-- --
	0	33 - 33	44 - 40	43 - 39	-- --
	7	32 - 27	34 - 32	31 - 35	27 - 28
	7	45 - 48	48 - 50	49 - 50	39 - 47
	15	35 - 35	40 - 41	41 - 35	26 - 33
	15	43 - 43	44 - 44	49 - 48	16 - 19
9 Hours	0	47 - 37	48 - 50	48 - 48	40 - 49
	0	37 - 44	45 - 44	44 - 45	32 - --
	7	43 - 46	50 - 49	50 - 48	40 - 47
	7	36 - 36	49 - 48	48 - 50	30b- 23b
	15	40 - 40	48 - 50	47b- 50	37 - 30
	15	41 - 46	49 - 50	46 - 49	18b- 26b

Appendix 2

CONTROLLED TEMPERATURE EXPERIMENT
Germination of Samples Treated at 40% Dry Matter Stage of Maturity. 12 Day Count.

Frost Exposure 4°F.	Harvest Days after Treatment	NOVEMBER A - B	JANUARY A - B	APRIL A - B	MAY A - B
None	0	49 - 49	50 - 50	49 - 48	38b- 45b
	0	43 - 44	48 - 42	37b- 45	27 - --
	7	50 - 49	49 - 50	50 - 50	47 - 42
	7	47 - 48	49 - 48	48 - 50	46 - --
	15	50 - 49	50 - 50	48 - 48	48 - 46
	15	49 - 49	50 - 48	48 - 48	31 - --
3 Hours	0	28 - 32	27 - 35	29 - 37	25 - 28
	0	42 - 37	37 - 35	42 - 41	22b- 40b
	7	31 - 28	27 - 29	29 - 32	20 - --
	7	46 - 44	48 - 50	48 - 49	42 - 44b
	15	20 - 15	20 - 16	9 - 21	22 - 15
	15	50 - 49	49 - 50	48 - 49	36 - 28
6 Hours	0	37 - 37	39 - 37	39 - 35	-- - --
	0	45 - 42	44 - 44	46 - 41	42 - --
	7	39 - 36	39 - 38	33 - 35	28 - 32
	7	47 - 49	48 - 50	49 - 50	39 - 48
	15	47 - 38	42 - 43	43 - 37	27 - 35
	15	47 - 49	45 - 46	49 - 48	29 - 23
9 Hours	0	50 - 45	48 - 50	48 - 48	42 - 49
	0	44 - 47	47 - 46	44 - 45	33 - --
	7	49 - 49	50 - 49	50 - 48	40 - 47
	7	45 -, 45	49 - 48	48 - 50	30b- 26b
	15	47 - 49	48 - 50	47 - 50	37 - 30
	15	47 - 50	49 - 50	46 - 49	20b- 28b

CONTROLLED TEMPERATURE EXPERIMENT
Germination of Samples Treated at 60% Dry Matter Stage of Maturity. 7 Day Count.

Frost Exposure 4°F.	Harvest Days after Treatment	NOVEMBER A - B	JANUARY A - B	APRIL A - B	MAY A - B
None	0	36 - 39	49 - 49	49 - 49	48 - 47
	0	44 - 40	49 - 46	50 - 48	27 - 39
	7	45 - 45	48 - 48	50 - 49	23 - 42b
	7	46 - 46	50 - 48	50 - 49	35 - 26b
	15	48 - 46	-- - --	-- - --	-- - --
	15	45 - 44	49 - 49	48 - 49	45 - 43
3 Hours	0	28 - 31	45 - 44	41 - 43	34 - 26
	0	39 - 37	49 - 49	48 - 48	-- - --
	7	35 - 41	49 - 46	47 - 45	28 - 37b
	7	44 - 42	44 - 39	46 - 44	21 - 33b
	15	26 - 33	38 - 32	38 - 37	38b- --
	15	41 - 46	41 - 48	48 - 49	30 - 36b
6 Hours	0	23 - 33	40 - 46	35b- 40	29 - 29
	0	38 - 35	50 - 50	48 - 50	33 - 45
	7	38 - 40	43 - 45	42 - 45	39 - 28b
	7	40 - 43	49 - 49	44 - 48	-- - --
	15	44 - 46	45 - 49	46 - 49	-- - --
	15	42 - 39	48 - 49	48 - 50	27b- --
9 Hours	0	36 - 32	40 - 45	47 - 47	29 - --
	0	34 - 36	42 - 38	40 - 44	38 - 38
	7	34 - 38	42 - 42	36 - 38	26 - 34b
	7	42 - 42	40 - 41	40 - 41	-- - --
	15	15 - 15	43 - 43	42 - 41	28b- --
	15	35 - 37	37 - 43	42 - 44	12 - 19b

CONTROLLED TEMPERATURE EXPERIMENT
Germination of Samples Treated at 60% Dry Matter Stage of Maturity. 12 Day Count.

Frost Exposure 4°F.	Harvest Days after Treatment	NOVEMBER A - B	JANUARY A - B	APRIL A - B	MAY A - B
None	0	47 - 48	49 - 49	49 - 49	48 - 47
	0	49 - 41	49 - 46	50 - 48	29 - 42
	7	49 - 50	48 - 48	50 - 49	27 - 46
	7	49 - 47	50 - 48	50 - 49	39 - 29
	15	48 - 48	-- - --	-- - --	-- - --
	15	47 - 47	49 - 49	48 - 49	46 - 45
3 Hours	0	43 - 44	46 - 45	48 - 45	34 - 28
	0	47 - 43	49 - 49	48 - 48	-- - --
	7	46 - 45	49 - 49	48 - 49	33 - 39
	7	46 - 44	48 - 45	47 - 48	22 - 35
	15	39 - 45	43 - 44	42 - 43	42 - --
	15	48 - 49	48 - 48	48 - 49	30 - 39
6 Hours	0	38 - 45	44 - 48	38 - 46	34 - 34
	0	45 - 44	50 - 50	48 - 50	35 - 46
	7	44 - 47	47 - 48	47 - 47	40 - 30
	7	45 - 47	49 - 49	47 - 48	-- - --
	15	49 - 49	49 - 49	48 - 49	-- - --
	15	48 - 49	48 - 49	48 - 50	33 - --
9 Hours	0	48 - 46	48 - 46	49 - 50	33 - --
	0	39 - 43	47 - 45	45 - 46	39 - 44
	7	41 - 46	43 - 43	40 - 43	28 - 38
	7	42 - 43	47 - 47	42 - 44	-- - --
	15	42 - 40	48 - 43	47 - 44	30 - --
	15	45 - 45	40 - 46	48 - 47	17 - 32

Appendix 5

Germination of Field Plot Samples Taken at Successive Intervals from End of Flowering 1936

Third Seeding - June 4th to September 4th. Seed Stored Outside.

Date Cut	Days after Poll'n.	Wght. in Grams	Percentage GERMINATION JANUARY 7 Day	JANUARY 12 Day	FEBRUARY 7 Day	FEBRUARY 12 Day	MARCH 7 Day	MARCH 12 Day	MAY 7 Day	MAY 12 Day	JULY 7 Day	JULY 12 Day	JULY 18 Day	
Aug. 2	0	12.8	--	31	--	64	--	--	--	--	--	--	--	
			--	43	--	46	--	--	--	--	--	--	--	
Aug. 4	2	14.0	69	86	80	92	58	85	45	47	16	85	85	o
			58	70	64	81	55	70	29	34	2	65	65	
Aug.6	4	18.4	81	82	91	92	88	91	--	--	72	72	72	o
			88	91	89	92	93	95	--	--	72	73	73	
Aug. 8	6	17.8	80	97	87	93	79	96	--	--	1	62	89	o
			75	95	70	88	87	97	--	--	0	44	88	
Aug.10	8	19.9	82	95	89	96	89	95	--	--	0	73	95	o
			90	95	90	95	90	88	--	--	1	55	84	
Aug.12	10	24.0	97	--	99	--	100	--	--	--	61	97	--	o
			98	--	99	--	98	--	--	--	86	98	--	
Aug.14	12	26.9	95	--	97	--	95	--	--	--	90	91	--	*
			99	--	96	--	98	--	--	--	72	76	--	
Aug.16	14	27.6	99	--	98	--	97	--	--	--	97	--	--	*
			97	--	98	--	98	--	--	--	84	87	--	
Aug.18	16	27.6	97	--	97	--	98	--	--	--	96	--	--	*
			98	--	95	--	98	--	--	--	99	--	--	
Aug.20	18	28.5	98	--	99	--	97	--	--	--	96	--	--	*
			99	--	99	--	98	--	--	--	84	87	--	
Aug.22	20	29.3	96	--	99	--	99	--	--	--	98	--	--	**
			98	--	99	--	98	--	--	--	99	--	--	
Aug.24	22	29.4	98	--	100	--	99	--	--	--	99	--	--	**
			99	--	99	--	99	--	--	--	99	--	--	
Aug.26	24	29.7	98	--	100	--	99	--	--	--	96	96	--	**
			99	--	100	--	99	--	--	--	99	--	--	
Aug.29	27	30.3	98	--	100	--	100	--	--	--	70	99	--	***
			99	--	97	--	99	--	--	--	88	98	--	
Aug.30	28	29.7	99	--	99	--	96	--	--	--	97	--	--	***
			98	--	98	--	99	--	--	--	99	--	--	

continuation.

Germination of Field Plot Samples Taken at
Successive Intervals from End of Flowering 1936

Third Seeding - June 4th to September 4th. Seed Stored Outside.

Date Cut	Days after Poll'. ø	Wght. in Grams.	PERCENTAGE GERMINATION JANUARY 7 Day	JANUARY 12 Day	FEBRUARY 7 Day	FEBRUARY 12 Day	MARCH 7 Day	MARCH 12 Day	MAY 7 Day	MAY 12 Day	JULY 7 Day	JULY 12 Day	JULY 18 Day
Sept.1	30	29.4	98	--	99	--	99	--	--	--	93	100-	--oo
			99	--	99	--	99	--	--	--	78	100-	--
Sept.4	33	30.6	99	--	99	--	100	--	--	--	10	97 --	o
			98	--	99	--	99	--	--	--	43	98 --	

* Tested July 6th.

** Tested July 7th.

*** Tested July 8th.

o Tested July 9th.

oo Tested July 10th.

ø Days from end of Pollination.

Third Seeding - Inside and Outside Storage
Cut September 4th. Five Plots. Mature

Inside Storage.

Plot No.	Date Cut.	Wght. in Grams	PERCENTAGE GERMINATION JANUARY 7 Day	JANUARY 12 Day	FEBRUARY 7 Day	FEBRUARY 12 Day	MARCH 7 Day	MARCH 12 Day	MAY 7 Day	MAY 12 Day	JULY 7 Day	JULY 12 Day	
9,,	Sept.4	27.3	98	--	99	--	99	--	--	--	99	--	*
			99	--	97	--	99	--	--	--	96	--	
17	"	29.2	99	--	100	--	98	--	--	--	100	--	*
			99	--	99	--	96	--	--	--	83-90		
22	"	28.8	99	--	100	--	100	--	--	--	98	--	*
			99	--	98	--	100	--	--	--	99	--	
25	"	29.5	98	--	98	--	99	--	--	--	99	--	*
			98	--	99	--	99	--	--	--	97	--	
32	"	29.3	98	--	98	--	100	--	--	--	97	--	*
			97	--	99	--	98	--	--	--	99	--	

Outside Storage.

9	Sept.4	29.7	98	--	100	--	99	--	--	--	63-98		o
			97	--	98	--	99	--	--	--	30-97		
17	"	29.6	97,,	--	97	--	99	--	--	--	14-95		o
			100	--	98	--	98	--	--	--	40-97		
22	"	29.1	99	--	100	--	99	--	--	--	90-100		o
			96	--	99	--	100	--	--	--	45-99		
25	"	30.3	100	--	96	--	99	--	--	--	32-100		o
			98	--	99	--	99	--	--	--	62-94		
32	"	29.7	98	--	95	--	98	--	--	--	30-96		o
			98	--	95	--	99	--	--	--	34-99		

* Tested July 23rd.

o Tested July 10th.

Appendix 8

Germination of Field Plot Samples 1936
Fourth Seeding. Six Plots Sampled on Each Date.

Cut September 5th.

Outside Storage.

Plot No.	Wght. in Grams	PERCENTAGE GERMINATION JANUARY 7 Day	JANUARY 12 Day	FEBRUARY 7 Day	FEBRUARY 12 Day	MARCH 7 Day	MARCH 12 Day	MAY 7 Day	MAY 12 Day	JULY 7 Day	JULY 12 Day	Date of July Test.
1	27.3	96	--	98	--	97	--	--	--	98	--	14th
		99	--	98	--	98	--	--	--	98	--	
12	27.5	99	--	97	--	100	--	--	--	15-91b		14th
		97	--	99	--	100	--	--	--	55-93		
14	24.3	99	--	99	--	97	--	--	--	21-95		14th
		98	--	98	--	97	--	--	--	9-93		
21	25.8	98	--	98	--	98	--	--	--	36-99		14th
		98	--	95	--	98	--	--	--	35-99		
29	25.8	95	--	97	--	98	--	--	--	29-97		14th
		97	--	99	--	99	--	--	--	45-99		
34	26.3	98	--	97	--	98	--	--	--	76-97		14th
		97	--	97	--	98	--	--	--	44-100		

Inside Storage.

1	26.6	98	--	100	--	99	--	--	--	100	--	16th
		98	--	98	--	98	--	--	--	89-99		
12	26.1	96	--	97	--	99	--	--	--	98	--	16th
		99	--	99	--	98	--	--	--	88-97		
14	25.1	97	--	98	--	90-91		--	--	92-100		16th
		99	--	98	--	92-93		--	--	77-87 b		
21	24.0	98	--	98	--	92	--	--	--	92-95		16th
		98	--	99	--	97	--	--	--	99	--	
29	27.7	99	--	99	--	89-90b		--	--	97	--	16th
		99	--	98	--	99	--	--	--	90-97		
34	26.4	97	--	98	--	98	--	--	--	70-98		16th
		98	--	99	--	98	--	--	--	98	--	

Both inside and outside-stored seed appear to be affected in July tests beginning July 14th and 16th.

b Browning noted.

Fourth Seeding - continued.

Cut September 8th.

Outside Storage.

Plot No.	Wght. in Grams	PERCENTAGE GERMINATION JANUARY 7 Day	JANUARY 12 Day	FEBRUARY 7 Day	FEBRUARY 12 Day	MARCH 7 Day	MARCH 12 Day	MAY 7 Day	MAY 12 Day	JULY 7 Day	JULY 12 Day	Date of July Test.
1	26.8	99	--	99	--	98	--	--	--	37-96		14th
		98	--	99	--	99	--	--	--	46-100		
12	27.3	96	--	94-99		98	--	--	--	15-98		"
		98	--	99	--	98	--	--	--	65-96		
14	27.9	98	--	93-96		95-98		--	--	96	--	"
		96	--	99	--	99	--	--	--	73-99		
21	25.6	100	--	98	--	95-96		--	--	81-97		"
		99	--	100	--	87-93b		--	--	72-99		
29	27.3	99	--	94-99		98	--	--	--	67-99		"
		98	--	98	--	97	--	--	--	73-98		
34	27.2	99	--	98	--	89-91		--	--	76-97		"
		98	--	98	--	97	--	--	--	68-99		

Inside Storage.

1	28.4	98	--	98	--	94	--b	--	--	100	--	19th
		99	--	98	--	97	--	--	--	98	--	
12	26.5	98,	--	99	--	99	--	--	--	95	--	"
		97	--	98	--	98	--	--	--	96	--	
14	27.0	95	--	100	--	90-92		--	--	85-85b		"
		96	--	100	--	93-93		--	--	86-86b		
21	25.3	95	--	99	--	91	--	--	--	97	--	"
		96	--	100	--	99	--	--	--	98	--	
29	25.7	98	--	99	--	98,	--	--	--	95	--	"
		97	--	100	--	98	--	--	--	99	--	
34	26.8	97	--	98	--	99	--	--	--	97	--	"
		98	--	98	--	98	--	--	--	89-89b		

b Browning noted.

B29745